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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

This Issue

EUROPEAN CARS

Part I, Engines

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LUBRICATION

A TECHNICAL PUBLICATION DEVOTED TO THE SELECTION AND USE OF LUBRICANTS

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EUROPEAN CARS

PART I, ENGINES

ONE of the little known facts about the automobile industry is that the gasoline engine and car were invented and brought to a fairly advanced state of development in Europe, prior to the beginning of the 20th century. In fact, a successful self-propelled vehicle was built in Europe as early as 1885 by Gottlieb Daimler. In spite of this fact, it has only been since 1945 that European cars have received wide attention in the United States. Since this time and more particularly during the past three years, they have "caught on" and achieved considerable public acceptance. This recent interest has been brought about by a number of things. However, for the purposes of this article, it will suffice to say that their recent acceptance may be due to the fact that the imports have been able to demonstrate a degree of reliability, economy, convenience and styling which has caught the public fancy. Reliability has been improved and greatly assisted by many expanded and well stocked parts and service organizations. These have been broadened to the point where service for almost any European car is available in the large metropolitan areas, and for many makes service is available throughout the country. This, coupled with their traditional ease of operation and economy, together with their ability to utilize American fuels and oils, has done much to popularize the European cars. This popularity has reached remarkable proportions. It was estimated recently that their penetration into the U.S. new car market had approximated 7 per cent. This means that for every one hundred new cars sold, seven of the new cars were of European manufacture.

However, the purpose of this article is not to discuss the factors behind this phenomenal growth but to examine some of the major design features of these cars and to discuss their fuel and lubricant requirements.

While much has been written on the external design and styling features of European cars, this article will consider the technical aspects and begin with the engine, since it is the heart of the vehicle. A subsequent issue of "Lubrication" will discuss the design features of clutches, transmissions, differentials and suspensions. Table I (Pages 160-166) lists all of the 1957 and 1958 European cars on which information is available together with their major engine dimensions. The first thing which is immediately apparent is that there are almost 200 different models listed made by some 66 manufacturers. It is also apparent that there are a large number of different engine arrangements available. In addition, their displacements are small compared to the U.S. average. It is also evidenced that the 2 stroke cycle engine is widely used as is air as a direct engine coolant.

Since only one *diesel* engine is offered (optional in Mercedes-Benz 180D) this article will be mainly concerned with *gasoline* engines.

ENGINE ARRANGEMENTS

Let us first consider the various engine arrangements which are available. There are single cylinder engines, two cylinder engines, two cylinder horizontally opposed engines, four cylinder in-line, four cylinder horizontally opposed, V-8, V-12, and of course the conventional straight 6 cylinder in-line engine. In addition to these more or less conventional engines there is the unique three cylinder in-line arrangement, as well as the V-4 and V-6 designs. This large number of variations is unusual when compared to those available in this country. All of the cars currently manufactured in the United States have engine designs using either the four cylinder in-line, six cylinder in-line, or V-8 cylinder arrangement.

ENGINE DISPLACEMENTS

Aside from the large number of different engine arrangements, there is also a wide range of displacements used in European cars. As seen in Figure 1, they range all the way from 12 cubic inches up to 304 cubic inches. This does not include those special designs, such as the Facel Vega, which use larger American engines. The average displacement of all European cars is about 120 cubic inches. This is small compared to the average of 1958 United States car production of 325 cubic inches. As shown in Figure 1 it is also evident that there are a large number of cars having very small relative displacements, many of which are below 61 cubic inches and some even less than 30 cubic inches. European practice is to express engine size in terms of cubic centimeters (c.c.) or liters (l.) where one liter is equal to 1000 c.c. However, for this discussion, cubic inches will be used. For ease of conversion, one liter is equal to approximately 61 cubic inches.

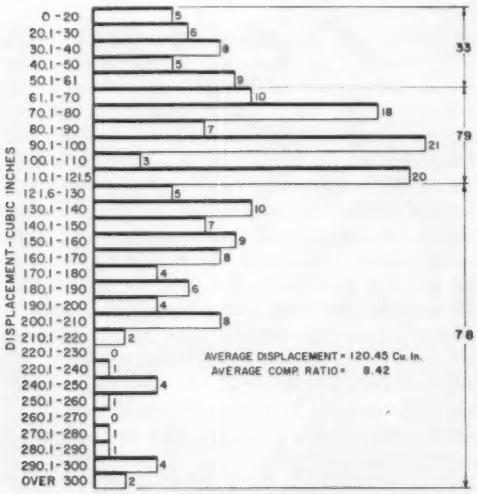
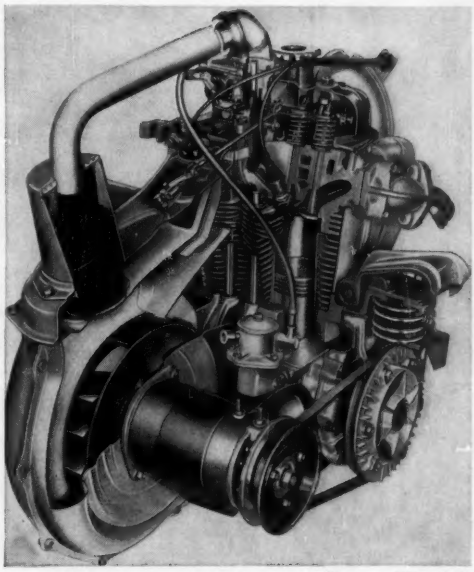


Figure 1 — Distribution of European passenger car engine displacement.



Courtesy of Fiat, Italy

Figure 2 — Fiat 500 engine.

Above this displacement group is the very popular 61 to 121.5 cubic inch displacement class (one to two liters). This group includes the vast majority of all the various models of European cars made. Perhaps one reason for the great popularity of this general displacement group is that not only are many family type sedans or saloons available in this class, but the group also includes many high performance sports cars.

The third general displacement group can be considered to include those engines whose cubic capacity is above 121.5 cubic inches. This class generally includes not only the upper middle price range of large family cars but many special models whose designs first appeared in former Grand Prix racing cars. Also included in this class are the few special makes using a large U.S. engine.

The Under 61 Cubic Inch Displacement Group

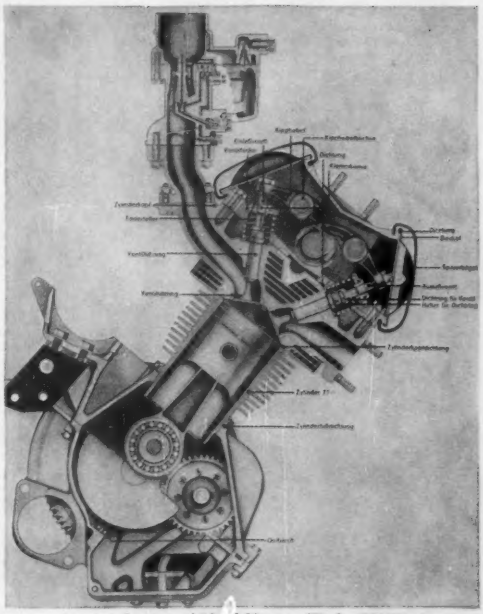
Since cars having displacements under 61 cubic inches are very popular in Europe, an examination of the economics involved will help to explain this great popularity. One of the reasons is the high price of gasoline in the European area which generally runs from two to five times that of the United States. In addition to this, a purchase tax is imposed on the car which may be as much as 50 per cent of the list purchase price. In many cases, it is based on

engine size. To reduce this tax and therefore broaden the market potential, engine sizes are kept small. Aside from these points, perhaps the major factor is the economic level of the available purchasing market. This is much lower than in this country and makes a real economy car almost mandatory if personal family transportation needs are to be met. The wide range of prices available are also necessary since it is not uncommon for a man to advance from a bicycle to a motor scooter and thus to successive sizes of small cars as his economic status improves with the years. While much of this movement is done in the used car market, a relatively low new car price must be established to make this possible.

Design Economies of the Small Car

A study of these designs will do much to explain why many of the economy cars can be made so cheaply. The first point, engine size, has already been covered. It is obvious that if only from a material standpoint, small engines can be made more cheaply than large engines. The second point is that many manufacturers use one or two cylinder air-cooled engines which do away with the necessity for a radiator and attending complications. This is a logical approach to the cooling and cost problem and is ideally suited to small engines. It is also ideal since it permits the use of many air-cooled designs which originated as motorcycle engines, and thus have had their "trial by fire". There are many cars using air cooled engines, among which are the BMW Isetta 300 and 600, Citroen 2CV, the Deutsch-Bonnet, the Fiat 500, the Goggomobil, the Lloyd, the Messerschmitt, the Dyna Panhard, and the Styer-Puch 500. An excellent example of this general design is shown in Figure 2 which depicts the Fiat 500 engine. Another interesting and economical design is found in the Citroen 2CV. In addition to being air-cooled, the Citroen 2CV engine contains additional design economies such as a three piece crank shaft and solid connecting rods. These are assembled on the crankshaft prior to the final assembly which is accomplished by pressing the two crank shaft halves into the central oval web. Although this requires special tools for both assembly and disassembly, it does reduce the number of machining operations required and therefore lowers costs. This engine also dispenses with the distributor, and by using a simple crankshaft-operated set of contact points, causes both spark plugs to fire on each engine revolution. The spark plug is thus fired at the end of the compression stroke to ignite the charge and again as the exhaust stroke is completed. However, the additional firing of the spark plug is of no consequence since there is no combustible gas to ignite in the cylinder during the exhaust stroke.

Design and construction economies do not always



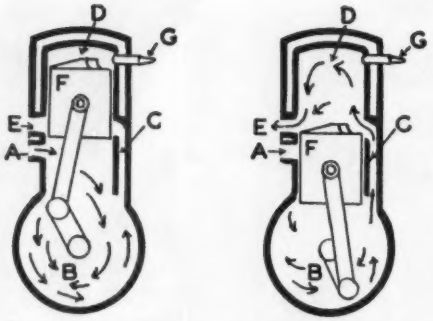
Courtesy of Lloyd Motoren Werke GMBH, Germany

Figure 3 — Lloyd 600 engine with single overhead camshaft.

dominate the small air-cooled engines, as illustrated by the Lloyd 600 which is shown in Figure 3. This engine makes use of an overhead camshaft, which shortens the valve train by eliminating push rods and lifters, thereby reducing thermal effects on valve lash and avoiding such compensating devices as hydraulic lifters. It also provides one method for inclining the valves to give a hemispherical combustion chamber. In addition to this, the connecting rods are mounted on the crankshaft by mean of roller bearings. These points usually entail a greater manufacturing expense, however prevailing labor and engineering costs apparently allow the economical use of these relatively expensive design features.

Lubrication of Four-Stroke Air-Cooled Engines

The four-stroke engine requires four separate motions of the piston (two crankshaft revolutions) to perform induction, compression, firing and exhaust, and thereby obtain one power stroke. Some *air-cooled* four stroke engines may be difficult to lubricate since the use of air-cooling tends to increase the operating temperatures of the engine and thereby imposes a heat load on the lubricant greater than would normally be encountered in a water cooled engine. It had been traditional that four-stroke air-cooled engines used only straight mineral oils unfortified with any additive to improve their operating characteristics or to promote engine cleanliness. This was done on the false premise that addi-



Upward (compression) stroke compresses mixture in cylinder "D" in preparation for ignition. Simultaneously, it creates a partial vacuum in the crankcase so that, as intake port "A" is uncovered fuel-oil-air mixture for a new charge flows in from the carburetor. At the end of the upward (compression) stroke, spark plug "G" ignites the compressed mixture.

The resulting combustion pressure forces the piston downward (power stroke) furnishing power to turn the propeller. As piston descends it closes intake port "A" and compresses mixture charge in the crankcase. Towards the end of the stroke exhaust port "E" is opened; then bypass port "C" is opened which permits new mixture to flow into cylinder "D", displacing the burned gases through exhaust port "E".

Figure 4 — Operation of a two stroke cycle engine.

tive type oils might increase combustion chamber deposits and therefore presumably contribute to combustion difficulties such as detonation or surface ignition. However, under severe temperature conditions, the oil with no additives has insufficient resistance to oxidation and tends to cause varnish as well as deposit formations, particularly around the piston rings. This in turn promotes oil consumption which adds to the combustion chamber deposits and leads to the very things that were to be avoided, namely combustion chamber deposits. Arguments on these points have raged for many years but it is only recently that manufacturers of four stroke air-cooled engines have approved the use of "HD" type oils for use in their engines. Among these are BMW Isetta, Fiat, Lloyd, Panhard, Porsche, and Volkswagen. All of these except Porsche also permit the use of Multi-Grade oils like the 10W-30.

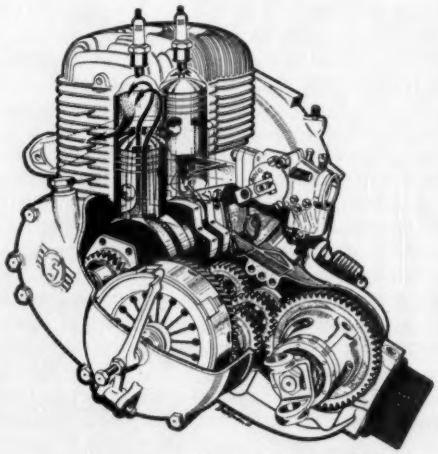
Use of Two-Stroke Engines

Although the four-stroke air-cooled engine is very popular, not all of the small air-cooled engines use this operating principle. Many have adopted the two stroke principle wherein the cylinder fires every revolution of the crank-shaft. The two-stroke engine operating cycle is quite simple and is shown in Figure 4. A complete power cycle consisting of induction, compression, firing, and exhaust is accomplished with only one up and down motion of the piston. This is why such an engine is called a two-stroke engine.

Since the mixture is first taken into the crankcase and then transferred to the cylinder, the two-stroke design tends to give a rough idle, but has excellent reliability. Among its advantages are that valve adjustments are not necessary. Also, good performance can be obtained from a relatively modest engine size. However, this design does impose a slight economy penalty. This is caused by its operating cycle which requires that inlet gases, under pressure, be used to scavenge the exhaust gases remaining from the previous power stroke. By proper selection of the crankcase scavenging pressure and careful intake and exhaust port placement, this penalty can be held to very modest limits. The Goggomobil T-400 engine is a good example of this type of design and is shown in Figure 5 (which also shows the combined clutch and transmission).

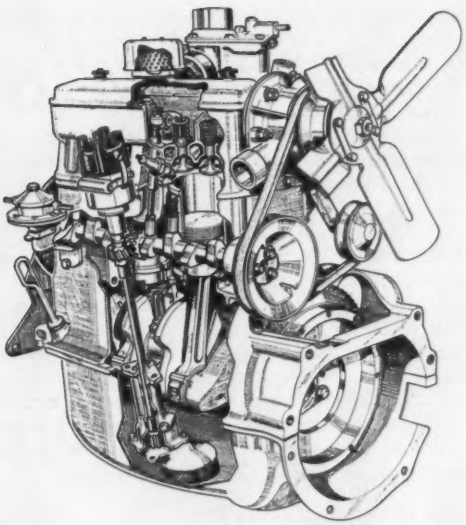
Lubrication of Two-Stroke Engines

Lubrication of the two-stroke engine requires an entirely different technique from that which is used for the conventional four-stroke designs. Most four-stroke engines use the crankcase as an oil sump from which the oil is circulated either by a pressure or a splash system. However in the two-stroke engine, the crankcase is used to compress the incoming fuel-air charge and push it into the cylinder through a port in the cylinder wall as the piston comes to the bottom of its stroke. Under these conditions oil cannot be retained in the crankcase and must be supplied by some other means. Traditionally this has been done by mixing the oil with the fuel in some proportion so as to provide lubrication for the moving parts of the engine. It is usual to use oil-fuel ratios of from 1:25 to 1:40. This means that for every 25 gallons of gasoline burned, one gallon of oil is also burned. This oil consumption rate is from six to ten times that experienced in most European four-stroke



Courtesy of Goggomobil, Germany

Figure 5 — Goggomobil T-400 two-stroke cycle engine with clutch and transmission.



Courtesy of Renault, France

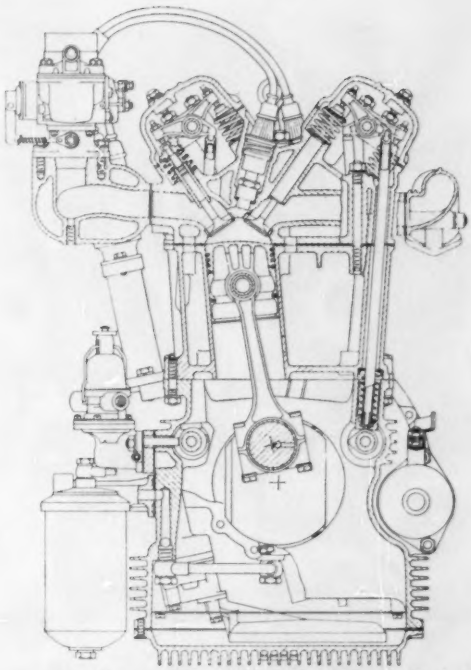
Figure 6 — Renault Dauphine four cylinder in-line water-cooled engine.

engines and accounts for the fact that straight mineral oils are usually recommended for two-stroke engines.

While the foregoing discussion may indicate that all economy cars are air-cooled, this is not so. By referring to Table I it can be seen that there are many cars which use more or less conventional four-cylinder in-line engine arrangements. Some of these engines, although water cooled are only slightly larger than the air-cooled engines.

Among these are the Austin A-35, Austin-Healey Sprite, the Fiat 600 Mutipla and 1000 TV, the Ford Taunus 15M, the Goliath GP 900 E and 1100, the Kieft MT-1, the Morris Minor 1000, the Renault 4-CV and Dauphine, and the Standard Eight. A typical engine of this general class is the Renault Dauphine which is shown in Figure 6. Also in this general displacement class is the Lancia Appia shown in Figure 7. This is a most unusual design having a four cylinder "Vee" type of cylinder arrangement staggered so that the angle between the two banks of cylinders is only 12°.

Another unique engine design in the small displacement class is the DKW and Saab engine. This engine has only three cylinders arranged in-line and operates on the two stroke cycle with water cooling. It was developed by DKW and is used by Saab under a licensing agreement. In its larger size as made by DKW it produces 40 BHP at 4250 RPM. The Saab version gives 38 BHP at 5000 RPM and is shown in Figure 8. The recently announced Saab Gran Turismo 750 uses the same engine in a higher state of "tune" and develops 50 BHP at 5000 RPM.

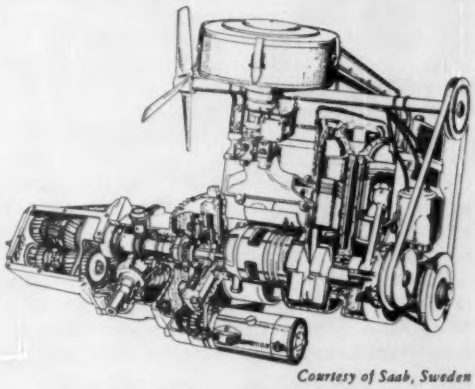


Courtesy of "Automobile Engineer," London, England

Figure 7 — Lancia Appia V-4 engine.

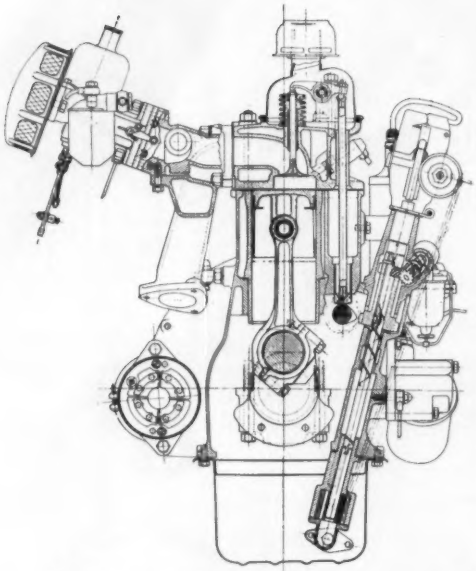
When this engine is equipped with a factory supplied racing kit, it can deliver 57 HP. This car is not in the true economy class despite its displacement since it is equipped with many extras which place it well up in the price range. Also in this general displacement category are the Lotus and small OSCA models. Both of these are primarily racing engines which utilize a double overhead cam design.

A word about engine "tune" may be in order here.



Courtesy of Saab, Sweden

Figure 8 — Saab 93B three cylinder two-stroke cycle engine with gearbox and differential unit attached.



Courtesy of Standard-Triumph Motor Car Co., Inc., New York

Figure 9 — Triumph TR-3 four cylinder engine showing wet cylinder liners.

Generally, the more highly tuned engines have had greater attention paid to obtaining the maximum power output of which that particular design is capable. This usually entails several modifications so as to improve engine "breathing". Among these are the use of multiple carburetors, and the increasing of intake port areas. Camshaft modifications are also made so as to cause the valves to stay open longer. In addition to these changes, compression ratios and engine speeds are also increased. Higher engine speeds, together with the increased "breathing" ability, allows the engine to burn a greater amount of fuel in a given time and thus do more work. An increase in compression ratio extracts more useful work from the fuel that is being burned. All of these modifications improve the power output of an engine, but at the same time, increase the stresses to which the engine is subjected.

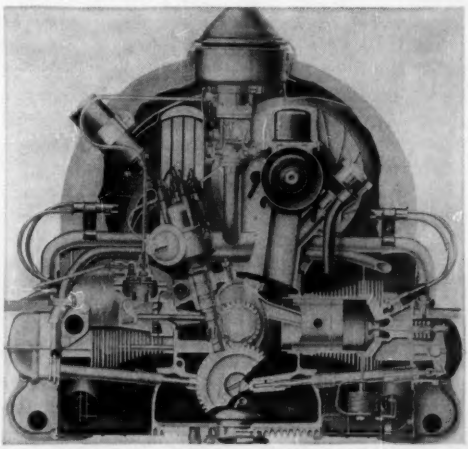
In keeping with the high price of gasoline in the British and European areas, many of these small cars have exceptional fuel economies. These range all the way from 30 miles per U.S. Gallon (MPG) to over 60 MPG. These higher values are only obtainable from the very small economy cars having displacements of 30 cubic inches or less. The average of the cars in this general displacement is around 35-40 MPG under normal intercity driving conditions where excessive speeds are not maintained.

Four-Stroke Water-Cooled Engine Lubrication

The lubrication requirements of these small displacement four-stroke water cooled engines are not severe. All of these engines except the strictly racing models have so called "wet" sumps in which all of the engine oil is carried and circulated from the crankcase and there is no outside oil tank. The oil capacities of these small engines is rather large compared to engines of larger displacement. A majority of the engines carry oil charges ranging from 2.6 to 3.9 quarts. However, the Renault 4-CV uses only 2.1 quarts, whereas the OSCA 1100 uses 6.3 quarts. Since all of these engines are under 70 cubic inch displacement, their displacement per quart of oil is much lower than the larger European cars and that of the average American car. The relatively large oil charge further reduces the demands placed on the oil by these small engines under normal driving conditions. However, under cold weather conditions, a longer time must be taken to insure complete warm up of the engine since there is a relatively large volume of oil involved.

The 61 to 121.5 Cubic Inch Displacement Group

The next displacement group above the strictly economy cars, are those engines whose sizes range from 61 to 121.5 cubic inches. This group includes many of the sports cars and a large number of medium size family sedans. Well over 50 per cent of all European car models are in this displacement range. Their popularity is probably due to the fact that reasonable economy, as well as acceptable performance can be obtained with engines in this displacement class. Their gasoline economy, while not in the 35 and up MPG range of the economy cars, is an acceptable 25 to 35 MPG under normal driving



Courtesy of Volkswagen GMBH, Germany

Figure 10 — Volkswagen four cylinder horizontally opposed air-cooled engine.

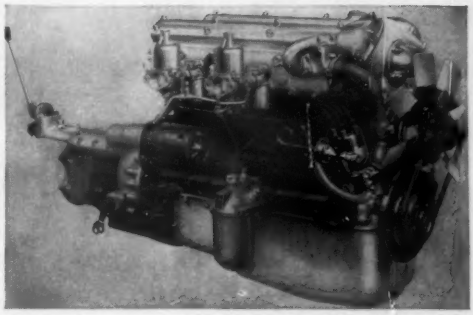
conditions. Performance, although not up to the average of U.S. production cars, is acceptable by European standards. While many of these engine designs have relatively modest displacements, they are available in several states of tune. This makes it possible to utilize the same engine in both the family sedan and its sports car counterpart. The MG, the Triumph TR-3, the Morgan, the Mercedes-Benz 190 SL and the Alfa Romeo Veloce are a few examples where a more highly tuned version of a basic engine is used in a sports car.

Together with this interchange of engines within a specific make, there is also considerable interchange of basic engines between cars. This is particularly true of those cars manufactured by the British Motor Corporation. This company makes three basic engines, their "A", "B", and "C" sizes. The "A" engine is used only in the Austin A-35 and Morris Minor. The "B" engine is used in the Austin A-50 and A-55, the Morris Oxford and Cowley, the Wolseley Fifteen-Fifty and Fifteen Hundred, the MG Magnette and MGA, and the Metropolitan (which is made for sale by Nash Motors Division of American Motors in the United States). The "C" engine is used in the Austin A-95 and A-105, the Wolseley Six-Ninety, and the Austin-Healey 100-Six. To a lesser degree, the Rootes Group in England also makes multiple use of a basic engine. This company uses the same engine in both their Sunbeam Rapier and their Hillman Minx and Hillman Husky Series 1. It is also a well-known fact that Rolls-Royce and Bentley use the same engine.

Most of the engine designs in this displacement range are four-cylinder in-line, four-cycle water cooled engines, although some of the larger cars use a different cylinder arrangement. Among these are AC, Frazer-Nash, Vauxhall, Porsche, and Volkswagen. Both AC and Frazer-Nash use six-cylinder in-line engines in all models, whereas Porsche and Volkswagen utilize four-cylinder horizontally opposed air-cooled engines in all models. A typical example of the four-cylinder in-line engine is the Triumph TR-3 engine shown in Figure 9. The horizontally opposed four-cylinder air-cooled Volkswagen engine is shown in Figure 10.

The Over 121.5 Cubic Inch Displacement Group

Above 121.5 cubic inches are the larger displacement engines usually used in the upper middle priced and high priced cars. While a few of these engines are four-cylinder in-line, a vast majority are six-cylinder in-line. All are water cooled, except for the Tatra air-cooled V-8 engine. One of the most widely known engines is the Jaguar XK 150 engine shown in Figure 11. While this is a fairly large engine, with a displacement of 210 cubic inches, it

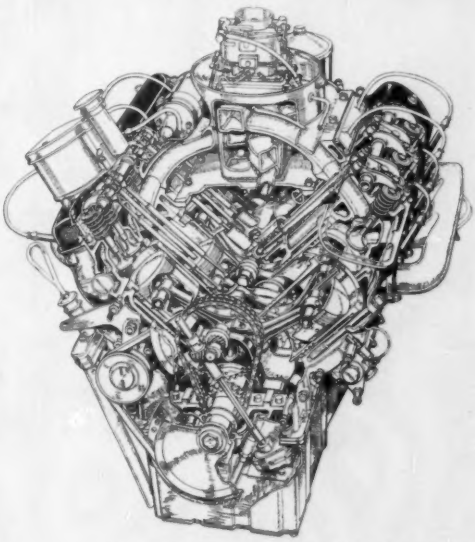


Courtesy of Jaguar Cars Ltd., England

Figure 11 — Jaguar XK-150 engine showing double overhead camshafts and twin S.U. side draft carburetors.

is an excellent example of a good and efficient design found in the quality imported car. Also in this large displacement class are found several V-8 engines and one V-12. The V-8 engines are found in such automobiles as BMW (Bayerische Motoren Werke AG), which is shown in Figure 12, the Maserati, the Simca Vidette, and the Tatra which was mentioned above. The V-12 engine is used only by the Italian Ferarri. An unusual V-6 engine is found in the Lancia, which is also produced in Italy. This engine is composed of two banks of three cylinders each, having a 60° included angle between the two banks of cylinders.

In spite of the large difference in size between



Courtesy of Bayerische Motoren Werke AG, Germany

Figure 12 — BMW 507 V-8 engine showing general arrangement of cylinders and valve gear.

TABLE I
Engine Statistics

Make	Model	Engine Location	Final Drive Location	Cylinders and Type	Valve Gear Type	Cooling Type	Bore and Stroke (in.)	Displacement (cu. in.)	Compression Ratio	HP at RPM	HP/cubic in.	No. of Carbs. and Make
AC (Britain)	Ace	F	R	6-IL	SOHC	W	2.56 x 3.94	121.5	8.0	90 at 4500	0.74	3-S.U.
	Aceca	F	R	6-IL	SOHC	W	2.56 x 3.94	121.5	8.0	90 at 4500	0.74	3-S.U.
	Sedan (2 liter)	F	R	6-IL	SOHC	W	2.56 x 3.94	121.5	6.8	76 at 4500	0.62	3-S.U.
	Ace-Bristol	F	R	6-IL	P-OHV	W	2.60 x 3.78	120.2	8.5	120 at 5750	0.99	3-Solex
	Aceca-Bristol	F	R	6-IL	P-OHV	W	2.60 x 3.78	120.2	8.5	105 at 5000	0.86	3-Solex
Alfa Romeo (Italy)	1300 Giulietta Berlina	F	R	4-IL	DOHC	W	2.91 x 2.95	78.7	7.5	50 at 5200	0.63	1-Solex
	1300 Giulietta Spyder	F	R	4-IL	DOHC	W	2.91 x 2.95	78.7	8.0	65 at 6000	0.82	1-Solex
	1300 Giulietta Sprint Veloce	F	R	4-IL	DOHC	W	2.91 x 2.95	78.7	9.5	90 at 6000	1.14	2-Weber
	1900	F	R	4-IL	DOHC	W	3.32 x 3.46	110.5	7.5	90 at 4800	0.81	1-Solex
	1900 Super Sprint	F	R	4-IL	DOHC	W	3.32 x 3.46	110.5	8.0	115 at 5000	1.04	2-Solex
Allard (Britain)	Monte Carlo — Jaguar Engine	F	R	6-IL	DOHC	W	3.27 x 4.17	210.0	8.0	210 at 5500	1.00	2-S.U.
	Cadillac Engine	F	R	V-8	P-OHV	W	4.00 x 3.63	365.0	10.25	310 at 4800	0.85	1-Rochester
	Palm Beach Mk II — Jaguar Engine	F	R	6-IL	DOHC	W	3.27 x 4.17	210.0	8.0	190 at 5500	0.90	2-S.U.
	Zodiac Engine	F	R	6-IL	P-OHV	W	3.25 x 3.13	155.8	7.8	90 at 4400	0.57	3-Zenith
	J3 Racing Chrysler 300D Engine	F	R	V-8	P-OHV	W	4.00 x 3.90	392.0	10.0	380 at 5200	0.99	3-Carter
Alvis (Britain)	3 Liter	F	R	6-IL	P-OHV	W	3.30 x 3.54	182.6	8.0	104 at 4000	0.56	2-S.U.
Armstrong Siddeley (Britain)	Sapphire 346	F	R	6-IL	P-OHV	W	3.54 x 3.54	209.6	7.0	125 at 4700	0.59	1-Stromberg
	Sapphire 346 (Special)	F	R	6-IL	P-OHV	W	3.54 x 3.54	209.6	7.0	150 at 5000	0.71	2-Stromberg
	Sapphire 234	F	R	4-IL	P-OHV	W	3.54 x 3.54	139.8	7.5	120 at 5000	0.85	2-S.U.
	Sapphire 236	F	R	6-IL	P-OHV	W	2.76 x 3.94	140.9	7.5	85 at 4500	0.60	1-Stromberg
Aston Martin (Britain)	DB 2-4, Mk II	F	R	6-IL	DOHC	W	3.27 x 3.54	178.0	8.2	140 at 5000	0.78	2-S.U.
	DB 3S	F	R	6-IL	DOHC	W	3.27 x 3.54	178.0	8.7	210 at 5500	1.17	3-Weber
	DB Mk III	F	R	6-IL	DOHC	W	3.27 x 3.54	178.0	8.2	162 at 5500	0.90	2-S.U.
Austin (Britain)	A 35	F	R	4-IL	P-OHV	W	2.48 x 3.00	57.8	8.3	34 at 4750	0.58	1-Zenith
	A 50 & A 55	F	R	4-IL	P-OHV	W	2.88 x 3.50	90.9	8.3	51 at 4250	0.56	1-Zenith
	A 95	F	R	6-IL	P-OHV	W	3.13 x 3.50	161.1	8.3	92 at 4500	0.55	1-Zenith
	A 105	F	R	6-IL	P-OHV	W	3.13 x 3.50	161.1	8.3	102 at 4600	0.63	2-S.U.
	Princess	F	R	6-IL	P-OHV	W	3.44 x 4.38	243.6	7.6	150 at 4100	0.61	2-S.U.
Austin Healey (Britain)	BN4 (100-six)	F	R	6-IL	P-OHV	W	3.13 x 3.50	161.1	8.3	102 at 4600	0.63	2-S.U.
	Sprite	F	R	4-IL	P-OHV	W	2.47 x 3.00	57.8	8.3	48 at 5000	0.83	2-S.U.

TABLE I (Cont'd)

Engine Statistics

Make	Model	Engine Location	Final Drive Location	Cylinders and Type	Valve Gear Type	Cooling Type	Bore and Stroke (in.)	Displacement (cu. in.)	Compression Ratio	HP at RPM	HP/cubic in.	No. of Carbs. and Make
Bentley	S Series	F	R	6-IL	F	W	3.75 x 4.50	298.0	8.0	Not Available	—	2-S.U.
(Britain)	Continental	F	R	6-IL	F	W	3.75 x 4.50	298.0	8.0	Not Available	—	2-S.U.
Berkeley	328 cc	F	F	2-IL	2 stroke	A	2.28 x 2.44	20.0	8.2	18 at 5250	0.90	2-Amal
(Britain)	492 cc	F	F	3-IL	2 stroke	A	2.28 x 2.44	30.0	7.5	30 at 5500	1.00	3-Amal
BMW	501 (6 cyl.)	F	R	6-IL	P-OHV	W	2.68 x 3.78	126.7	7.0	72 at 4500	0.56	1-Solex
(Germany)	501 (V-8)	F	R	V-8	P-OHV	W	2.91 x 2.95	157.4	7.0	100 at 4800	0.63	1-Solex
	502 S	F	R	V-8	P-OHV	W	3.23 x 2.95	193.3	7.5	140 at 4800	0.72	2-Solex
	503	F	R	V-8	P-OHV	W	3.23 x 2.95	193.3	7.5	140 at 4800	0.72	2-Solex
	507	F	R	V-8	P-OHV	W	3.23 x 2.95	193.3	7.8	150 at 5000	0.77	2-Solex
	Isetta 300	R	R	1	2 stroke	A	2.84 x 2.86	18.3	7.1	13 at 5800	0.71	1-Bing
	Isetta 600	R	R	2-HO	P-OHV	A	2.92 x 2.68	21.0	6.5	19.5 at 4000	0.90	1-Bing
Bond (Britain)	Minicar, Mk E	F	F	1	2 stroke	A	2.33 x 2.85	12.0	NA	8.5 at 4000	0.71	Not Available
Borgward	Isabella 60	F	R	4-IL	P-OHV	W	2.95 x 3.32	91.1	6.6	60 at 4700	0.65	1-Solex
(Germany)	Isabella TS	F	R	4-IL	P-OHV	W	2.95 x 3.32	91.1	8.2	85 at 5200	0.77	1-Solex
Bristol	405	F	R	6-IL	P-OHV	W	2.60 x 3.78	120.2	8.5	105 at 5000	0.87	3-Solex
(Britain)	406	F	R	6-IL	P-OHV	W	2.70 x 3.92	134.7	8.5	105 at 4700	0.78	3-Solex
	Arnolt-Bristol Bolide	F	R	6-IL	P-OHV	W	2.70 x 3.92	134.7	9.1	130 at 5500	0.97	3-Solex
Citroen	DS 19	F	F	4-IL	P-OHV	W	3.07 x 3.94	116.5	7.5	80 at 5000	0.68	1-Zenith
(France)	ID 19	F	F	4-IL	P-OHV	W	3.07 x 3.94	116.5	6.8	62 at 4000	0.53	1-Solex
	2 CV	F	F	2-HO	P-OHV	A	2.60 x 2.44	25.9	7.0	12 at 3500	0.46	1-Solex
DAF (Holland)		F	R	2-HO	P-OHV	A	2.99 x 2.56	36.0	7.0	22 at 4000	0.61	1-Solex
Daimler	Century	F	R	6-IL	P-OHV	W	3.00 x 3.49	148.4	7.8	100 at 4400	0.67	2-S.U.
(Britain)	Regency (One-O-Four)	F	R	6-IL	P-OHV	W	3.25 x 4.25	211.5	7.6	137 at 4400	0.64	2-S.U
	Majestic	F	R	6-IL	P-OHV	W	3.40 x 4.25	231.6	7.5	147 at 4400	0.63	2-S.U.
	Regency Mk II	F	R	6-IL	P-OHV	W	3.75 x 4.25	281.7	7.0	167 at 3800	0.59	2-S.U.
Dellow (Britain)		F	R	4-IL	L	W	2.49 x 3.64	71.5	7.6	38 at 4400	0.53	1-Zenith
Deutsch-Bonnet (France)		F	F	2-HO	P-OHV	A	3.35 x 2.95	51.9	8.0	56 at 5700	1.07	1-Zenith
DKW (Germany)	3=6	F	F	3-IL	2 stroke	W	2.69 x 2.99	54.1	7.0	40 at 4250	0.73	1-Solex
(Auto Union)	1000 Coupe	F	F	3-IL	2 stroke	W	2.91 x 2.99	59.7	8.0	50 at 4500	0.84	1-Solex
Facel Vega (France)	HK 500	F	R	V-8	P-OHV	W	4.12 x 3.38	361.0	10.2	355 at 5200	0.98	2-Carter
Fairthorpe	Electron Minor	F	R	4-IL	P-OHV	W	2.48 x 2.99	57.4	8.0	38 at 5000	0.64	1-Solex
(Britain)	Atomota	R	R	2-IL	P-OHV	A	2.75 x 3.31	39.4	6.5	35 at 5700	0.89	1-Amal
Ferrari (Italy)	250 Gran Turismo	F	R	V-12	SOHC	W	2.87 x 2.31	180.1	9.0	240 at 7000	1.33	3-Weber

TABLE I (Cont'd)
Engine Statistics

Make	Model	Engine Location	Final Drive Location	Cylinders and Type	Valve Gear Type	Cooling Type	Bore and Stroke (in.)	Displacement (cu. in.)	Compression Ratio	HP at RPM	HP/cubic in.	No. of Carbs. and Make
Fiat (Italy)	La Nuova 500	R	R	2-IL	P-OHV	A	2.60 x 2.78	29.8	6.8	13 at 4000	0.43	1-Weber
	600, 600 Multipla	R	R	4-IL	P-OHV	W	2.36 x 2.20	38.6	7.5	22 at 4600	0.56	1-Weber
	1100	R	R	4-IL	P-OHV	W	2.60 x 2.96	66.5	7.0	40 at 4400	0.60	1-Weber
	1100 TV	F	R	4-IL	P-OHV	W	2.60 x 2.96	66.5	8.0	53 at 5200	0.79	1-Weber
	1200, Spyder	F	R	4-IL	P-OHV	W	2.83 x 2.45	74.5	8.0	55 at 5300	0.74	1-Weber
	1400 B	F	R	4-IL	P-OHV	W	3.23 x 2.60	85.0	7.5	58 at 4600	0.68	1-Weber
	1900 B	F	R	4-IL	P-OHV	W	3.23 x 3.54	116.0	7.5	80 at 4000	0.68	1-Weber
Ford (Britain)	Popular	F	R	4-IL	L	W	2.50 x 3.64	71.6	6.2	30 at 4000	0.41	1-Zenith
	Anglia, Prefect	F	R	4-IL	L	W	2.50 x 3.64	71.6	7.0	36 at 4500	0.50	1-Solex
	Consul, Consul Mk II	F	R	4-IL	P-OHV	W	3.25 x 3.13	103.9	7.8	61 at 4400	0.58	1-Zenith
	Zephyr, Zodiac	F	R	6-IL	P-OHV	W	3.25 x 3.13	155.8	7.8	90 at 4400	0.57	1-Zenith
Ford-Taunus (Germany)	12M	F	R	4-IL	L	W	2.50 x 3.64	71.5	6.8	43 at 4250	0.60	1-Solex
	15M	F	R	4-IL	P-OHV	W	3.23 x 2.79	91.4	7.1	60 at 4500	0.65	1-Solex
	17M	F	R	4-IL	P-OHV	W	3.31 x 3.02	103.6	7.1	60 at 4250	0.57	1-Solex
Frazer-Nash (Britain)	Sebring, Turismo	F	R	6-IL	P-OHV	W	2.60 x 3.80	120.2	9.0	140 at 5750	1.16	3-Solex
	Continental Coupe	F	R	V-8	P-OHV	W	3.23 x 2.95	193.3	7.8	140 at 5000	0.72	2-Solex
Goggomobil (Germany)	T-300	R	R	2-IL	2 stroke	A	2.28 x 2.21	17.8	6.5	17.5 at 6000	0.98	1-Bing
	T-400, TS-400	R	R	2-IL	2 stroke	A	2.64 x 2.20	23.8	6.0	20 at 5000	0.97	1-Bing
Goliath (Germany)	GP 900E	F	F	2-IL	2 stroke	W	3.31 x 3.15	54.1	7.5	40 at 4250	0.73	Fuel Injection
	1100 Delux	F	F	4-HO	P-OHV	W	2.91 x 2.52	66.7	7.9	62 at 5000	0.93	2-Solex
Hillman (Britain)	Minx	F	R	4-IL	P-OHV	W	3.00 x 3.00	84.8	8.0	51 at 4400	0.60	1-Zenith
	Minx Series III	F	R	4-IL	P-OHV	W	3.11 x 3.00	91.2	8.5	52.5 at 4300	0.58	1-Zenith
	Husky Series I	F	R	4-IL	P-OHV	W	3.00 x 3.00	84.8	7.0	43 at 4000	0.51	1-Zenith
Humber (Britain)	Hawk	F	R	4-IL	P-OHV	W	3.19 x 4.33	138.2	7.5	78 at 4400	0.56	1-Zenith
	Super Snipe Mk IV	F	R	6-IL	P-OHV	W	3.50 x 4.38	252.6	7.4	122 at 3800	0.48	1-Stromberg
Jaguar (Britain)	2.4 Liter	F	R	6-IL	DOHC	W	3.27 x 3.01	151.5	8.0	112 at 5750	0.74	2-Solex
	3.4 Liter	F	R	6-IL	DOHC	W	3.27 x 4.17	210.0	8.0	190 at 5500	0.90	2-S.U.
	XK-150	F	R	6-IL	DOHC	W	3.27 x 4.17	210.0	8.0	210 at 5500	1.00	2-S.U.
	Mark VIII	F	R	6-IL	DOHC	W	3.27 x 4.17	210.0	8.0	210 at 5500	1.00	2-S.U.
	D Type (Racing)	F	R	6-IL	DOHC	W	3.27 x 4.17	210.0	9.0	250 at 6000	1.19	3-Weber
Jensen (Britain)	541 Special	F	R	6-IL	P-OHV	W	3.43 x 4.37	243.0	7.4	Not Available	—	3-S.U.
	Interceptor	F	R	6-IL	P-OHV	W	3.43 x 4.37	243.0	6.8	130 at 3700	0.53	1-Stromberg
	541 R Series	F	R	6-IL	P-OHV	W	3.43 x 4.37	243.0	7.6	Not Available	—	2-S.U.
Kieft (Britain)	MT 1	F	R	4-IL	SOHC	W	2.85 x 2.63	67.0	9.8	83 at 6800	1.23	2-S.U.
Lagonda (Britain)	3 Liter	F	R	6-IL	DOHC	W	3.27 x 3.56	178.3	8.2	140 at 5000	0.78	2-S.U.
Lancia (Italy)	Aurelia 2500GT	F	R	V-6	P-OHV	W	3.07 x 3.36	149.4	8.4	118 at 5000	0.78	1-Weber
	Appia Series 2	F	R	V-4	P-OHV	W	2.67 x 2.95	66.5	7.2	43.5 at 4800	0.65	1-Solex
	Flaminia	F	R	V-6	P-OHV	W	3.15 x 3.21	150.0	8.0	112 at 4800	0.68	1-Solex

TABLE I (Cont'd)

Engine Statistics

Make	Model	Engine Location	Final Drive Location	Cylinders and Type	Valve Gear Type	Cooling Type	Bore and Stroke (in.)	Displacement (cu. in.)	Compression Ratio	HP at RPM	HP/cubic in.	No. of Carbs. and Make
Lloyd (Germany)	LP-600	F	F	2-IL	SOHC	A	3.03 x 2.52	36.4	6.6	24 at 4500	0.65	1-Solex
Lotus (Britain)	Eleven Club 75	F	R	4-IL	SOHC	W	2.85 x 2.63	66.9	9.8	85 at 6800	1.27	2-S.U.
	Eleven LeMans 85	F	R	4-IL	SOHC	W	2.85 x 2.63	66.9	9.8	85 at 6800	1.27	2-S.U.
	Eleven LeMans 100	F	R	4-IL	DOHC	W	2.99 x 3.15	89.2	8.6	100 at 6200	1.12	2-S.U.
	Eleven LeMans 150	F	R	4-IL	DOHC	W	2.99 x 3.15	89.2	NA	145 at 7000	1.62	2-S.U.
	Elite Coupe	F	R	4-IL	SOHC	W	2.99 x 2.62	78.8	NA	75 at 6600	0.95	2-S.U.
Maico (Germany)	500	R	R	2-IL	2 stroke	A	—— Not Available ——			21 at 4500	—	NA
Maserati (Italy)	200 S-1	F	R	4-IL	DOHC	W	3.62 x 2.96	121.5	9.5	190 at 7200	1.56	2-Weber
	A6G 200	F	R	6-IL	DOHC	W	3.13 x 2.75	122.0	9.0	150 at 6500	1.22	3-Weber
	Formula 1, 250F	F	R	6-IL	SOHC	W	3.38 x 3.00	152.0	12.0	270 at 7300	1.77	3-Weber
	300 S	F	R	6-IL	DOHC	W	3.38 x 3.63	182.0	9.5	260 at 6500	1.42	3-Weber
	450 S	F	R	V-8	DOHC	W	3.70 x 3.19	274.0	9.0	400 at 7000	1.45	4-Weber
	Gran Turismo 3500	F	R	6-IL	DOHC	W	3.39 x 3.95	212.6	8.5	230 at 5500	1.04	3-Weber
Meadows (Britain)	Frisky	R	R	2-IL	2 stroke	A	2.24 x 2.48	30.7	7.5	20 at 5000	0.65	NA
	Friskyport	R	R	2-IL	2 stroke	A	2.24 x 2.48	30.7	8.2	22 at 5500	0.72	NA
Mercedes-Benz (Germany)	180 A	F	R	4-IL	SOHC	W	3.34 x 3.30	115.4	6.8	74 at 4700	0.64	1-Solex
	180 Diesel	F	R	4-IL	SOHC	W	2.95 x 3.94	107.0	19.0	46 at 3500	0.43	Fuel Injection
	190	F	R	4-IL	SOHC	W	3.34 x 3.30	115.4	7.5	84 at 4800	0.72	1-Solex
	190 SL	F	R	4-IL	SOHC	W	3.34 x 3.30	115.4	8.5	120 at 5700	1.03	2-Solex
	219	F	R	6-IL	SOHC	W	3.06 x 2.88	134.0	8.7	100 at 5000	0.74	1-Solex
	220 S	F	R	6-IL	SOHC	W	3.06 x 2.88	139.0	8.7	120 at 5200	0.65	2-Solex
	300 D	F	R	6-IL	SOHC	W	3.34 x 3.47	183.0	8.6	180 at 5500	0.98	Fuel Injection
	300 SL	F	R	6-IL	SOHC	W	3.34 x 3.47	183.0	9.5	250 at 6200	1.36	Fuel Injection
Messerschmitt (Germany)	KR-200, 201	R	R	1	2 stroke	A	2.44 x 2.28	10.7	6.8	9.5 at 5250	0.88	NA
Metropolitan (USA-Britain)	B Series	F	R	4-IL	P-OHV	W	2.88 x 3.50	90.9	8.2	55 at 4600	0.60	1-Zenith
MG (Britain)	MGA	F	R	4-IL	P-OHV	W	2.88 x 3.50	90.9	8.3	72 at 5500	0.79	2-S.U.
	MGA Twin Cam	F	R	4-IL	DOHC	W	2.97 x 3.50	96.9	9.9	108 at 6700	1.10	2-S.U.
	Magnett (Series II)	F	R	4-IL	P-OHV	W	2.88 x 3.50	90.9	8.3	68 at 5200	0.74	2-S.U.
Morgan (Britain)	4/4 Series II	F	R	4-IL	L	W	2.50 x 3.64	71.6	7.0	36 at 4500	0.50	1-Zenith
	Plus 4	F	R	4-IL	P-OHV	W	3.27 x 3.62	121.5	8.5	100 at 5000	0.82	2-S.U.
Morris (Britain)	Minor 1000	F	R	4-IL	P-OHV	W	2.48 x 3.00	57.8	8.3	37 at 4750	0.64	1-S.U.
	Oxford (Series III), Cowley 1500	F	R	4-IL	P-OHV	W	2.88 x 3.50	90.9	8.3	55 at 4400	0.60	1-S.U.
	Isis (Series II)	F	R	6-IL	P-OHV	W	3.13 x 3.5	161.1	8.3	90 at 4500	0.55	1-S.U.

TABLE I (Cont'd)

Engine Statistics

Make	Model	Engine Location	Final Drive Location	Cylinders and Type	Valve Gear Type	Cooling Type	Bore and Stroke (in.)	Displacement (cu. in.)	Compression Ratio	HP at RPM	HP/cubic in.	No. of Carbs. and Make
NSU (Germany)	Prinz II	R	R	2-IL	SOHC	A	2.94 x 2.61	35.4	7.2	24 at 4800	0.68	1-Bing
Opel	Olympia, Record	F	R	4-IL	P-OHV	W	3.15 x 2.91	90.8	7.5	51.3 at 4200	0.56	1-Opel
(Germany)	Kapitan	F	R	6-IL	P-OHV	W	3.15 x 3.23	150.9	7.1	82 at 4000	0.54	1-Opel
O.S.C.A.	1100 2-AD	F	R	4-IL	DOHC	W	2.76 x 2.80	66.9	9.0	92 at 6600	1.38	2-Weber
(Italy)	1500 2-AD	F	R	4-IL	DOHC	W	3.07 x 3.07	90.9	9.5	135 at 6500	1.48	2-Weber
	2000 S	F	R	6-IL	DOHC	W	2.99 x 2.87	121.2	9.0	165 at 6500	1.36	3-Weber
	S187	F	R	4-IL	DOHC	W	2.44 x 2.44	45.7	9.0	70 at 7500	1.53	2-Weber
Panhard (France)	Dyna	F	F	2-HO	P-OHV	A	3.35 x 2.95	51.9	7.2	42 at 5000	0.80	1-Solex
Peugeot	203	F	R	4-IL	P-OHV	W	2.95 x 2.87	78.7	7.0	45 at 4500	0.57	1-Solex
(France)	403	F	R	4-IL	P-OHV	W	3.15 x 2.87	87.5	7.0	58 at 4900	0.66	1-Solex
Porsche	356A/1300	R	R	4-HO	P-OHV	A	2.94 x 2.91	78.7	6.5	44 at 4200	0.55	2-Solex
(Germany)	356A/1300S	R	R	4-HO	P-OHV	A	2.94 x 2.91	78.7	8.2	60 at 5500	0.76	2-Solex
	356A/1600	R	R	4-HO	P-OHV	A	3.25 x 2.91	96.5	7.5	60 at 4500	0.62	2-Solex
	356A/1600S	R	R	4-HO	P-OHV	A	3.25 x 2.91	96.5	8.5	75 at 5000	0.77	2-Solex
	356A61500G.S.	R	R	4-HO	DOHC	A	3.34 x 2.59	90.2	9.0	128 at 6400	1.41	2-Solex
	550A/1500 RS (Spyder)	R	R	4-HO	DOHC	A	3.34 x 2.59	90.2	9.0	135 at 7200	1.49	2-Solex
Renault	750 4 CV	R	R	4-IL	P-OHV	W	2.14 x 3.15	45.5	7.3	21 at 4200	0.46	1-Solex
(France)	Dauphine	R	R	4-IL	P-OHV	W	2.28 x 3.15	51.5	7.3	30 at 4250	0.58	1-Solex
	Fregate 2 Liter	F	R	4-IL	P-OHV	W	3.35 x 3.47	121.5	7.0	62 at 3800	0.51	1-Solex
	Fregate Standard	F	R	4-IL	P-OHV	W	3.47 x 3.47	130.7	7.0	77 at 4000	0.58	1-Solex
	Fregate Transfluide	F	R	4-IL	P-OHV	W	3.47 x 3.47	130.7	7.5	80.3 at 4000	0.61	1-Solex
Riley	1.5 Liter	F	R	4-IL	P-OHV	W	2.87 x 3.50	90.9	8.3	68 at 5400	0.74	2-S.U.
(Britain)	2.6 Liter	F	R	6-IL	P-OHV	W	3.63 x 3.50	154.6	8.5	101 at 4750	0.65	2-S.U.
	Pathfinder	F	R	4-IL	P-OHV	W	3.17 x 4.72	149.0	7.3	110 at 4400	0.73	2-S.U.
Rolls-Royce	Silver Cloud	F	R	6-IL	F	W	3.75 x 4.50	298.2	8.0	Not Available	—	2-S.U.
(Britain)	Silver Wraith	F	R	6-IL	F	W	3.75 x 4.50	298.2	8.0	Not Available	—	2-S.U.
Rover	60	F	R	4-IL	F	W	3.06 x 4.13	121.8	6.9	60 at 4400	0.49	1-S.U.
(Britain)	75	F	R	6-IL	F	W	2.88 x 3.50	136.0	7.2	80 at 4500	0.58	1-S.U.
	90E	F	R	6-IL	F	W	2.88 x 4.13	161.0	7.5	93 at 4500	0.57	1-S.U.
	105S	F	R	6-IL	F	W	2.88 x 4.13	161.0	8.5	108 at 4250	0.67	2-S.U.
	105 R	F	R	6-IL	F	W	2.88 x 4.13	161.0	8.5	108 at 4250	0.67	2-S.U.
Saab	93B	F	F	3-IL	2 stroke	W	2.59 x 2.87	46.0	7.3	38 at 5000	0.83	1-Solex
(Sweden)	GT750	F	F	3-IL	2 stroke	W	2.59 x 2.87	46.0	9.0	50 at 5000	1.09[a]	1-Solex

[a] 1.24 with dual carb speed kit developing 57BHP at 5200 RPM.

TABLE I (Cont'd)
Engine Statistics

Make	Model	Engine Location	Final Drive Location	Cylinders and Type	Valve Gear Type	Cooling Type	Bore and Stroke (in.)	Displacement (cu. in.)	Compression Ratio	HP at RPM	HP/cubic in.	No. of Carbs. and Make
Simca (France)	Aronde, Ariane 4	F	R	4-IL	P-OHV	W	2.91 x 2.95	78.7	6.8	48 at 4500	0.60	1-Solex
	Montlhery	F	R	4-IL	P-OHV	W	2.91 x 2.95	78.7	7.8	57 at 5200	0.72	1-Solex
	Vedette, Ariane V-8	F	R	V-8	L	W	2.60 x 3.31	143.4	7.5	84 at 4800	0.58	1-Zenith
Singer (Britain)	Gazelle	F	R	4-IL	SOHC	W	2.87 x 3.52	91.4	7.5	52.5 at 4500	0.57	1-Solex
Skoda (Czechoslovakia)	440	F	R	4-IL	P-OHV	W	2.68 x 2.97	66.4	7.0	40 at 4200	0.60	1-Jikov
	445	F	R	4-IL	P-OHV	W	2.83 x 2.97	74.5	7.0	45 at 4200	0.60	1-Jikov
	450	F	R	4-IL	P-OHV	W	2.63 x 2.97	66.4	8.4	50 at 5500	0.75	1-Jikov
	1201	F	R	4-IL	P-OHV	W	2.83 x 2.97	74.5	7.0	45 at 4200	0.60	1-Jikov
Standard (Britain)	Eight	F	R	4-IL	P-OHV	W	2.28 x 2.99	49.0	8.3	33 at 5000	0.67	1-Solex
	Ten	F	R	4-IL	P-OHV	W	2.48 x 2.99	57.8	8.0	38 at 5000	0.64	1-Solex
	Ensign	F	R	4-IL	P-OHV	W	2.99 x 3.62	102.0	8.0	60 at 4000	0.58	1-Solex
	Vanguard III	F	R	4-IL	P-OHV	W	3.35 x 3.62	127.6	7.5	68 at 4200	0.53	1-Solex
	Vanguard Sports	F	R	4-IL	P-OHV	W	3.35 x 3.62	127.6	8.0	90 at 4500	0.70	2-S.U.
Steyr-Puch (Austria)	500	R	R	2-HO	P-OHV	A	2.76 x 2.52	30.0	6.5	16 at 4600	0.53	1-Weber
Sunbeam (Britain)	Mark III	F	R	4-IL	P-OHV	W	3.19 x 4.33	138.2	7.5	85.5 at 4400	0.61	1-Stromberg
	Rapier	F	R	4-IL	P-OHV	W	3.00 x 3.00	84.8	8.0	67 at 5400	0.79	2-Zenith
Talbot (France)	2500 Rapide	F	R	4-IL	P-OHV[1]	W	3.53 x 3.90	152.5	7.6	120 at	0.79	1-Solex
	Talbot-America	—— Not Available ——								—— Not Available ——		
Tatra (Czechoslovakia)	603 V-8	R	R	V-8	P-OHV	A	2.95 x 2.83	155.5	6.5	100 at 4800	0.64	2-Jikov
Triumph (Britain)	TR-3	F	R	4-IL	P-OHV	W	3.27 x 3.62	121.5	8.5	100 at 5000	0.82	2-S.U.
	Ten	F	R	4-IL	P-OHV	W	2.48 x 2.99	57.8	8.0	38 at 5000	0.64	1-Solex
Vauxhall (Britain)	Victor	F	R	4-IL	P-OHV	W	3.13 x 3.00	92.0	7.8	54.8 at 4200	0.59	1-Zenith
	Velox, Cresta PA	F	R	6-IL	P-OHV	W	3.13 x 3.00	138.0	7.8	82.5 at 4400	0.59	1-Zenith
Volkswagen (Germany)		R	R	4-HO	P-OHV	A	3.03 x 2.52	72.7	6.8	36 at 3700	0.49	1-Solex
Volvo (Sweden)	PV-444L	F	R	4-IL	P-OHV	W	3.13 x 3.15	97.6	8.2	85 at 5500	0.82	2-S.U.
Wolseley (Britain)	Fifteen Hundred	F	R	4-IL	P-OHV	W	2.88 x 3.50	90.9	7.2	50 at 4200	0.55	1-S.U.
	Fifteen-Fifty	F	R	4-IL	P-OHV	W	2.88 x 3.50	90.9	8.3	55 at 4400	0.61	1-S.U.
	Six Ninety	F	R	6-IL	P-OHV	W	3.13 x 3.50	161.1	8.3	97 at 4500	0.60	2-S.U.

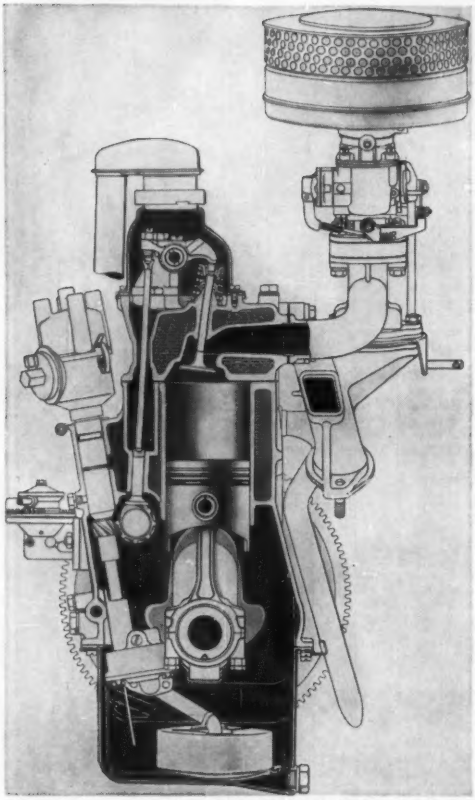
[1] 2 Camshafts in Engine Block.

Note: Abbreviations used in above table are as follows:

F = Front
R = Rear
C = Center
IL = In Line

W = Water Cooling
A = Air Cooling
HO = Horizontal Opposed
P-OHV = Push Rod Operated Overhead Valves

SOHC = Single Overhead Cam
DOHC = Double Overhead Cam
F = "F" Head Design
L = "L" Head Design



Courtesy of Ford Werke AG, Germany

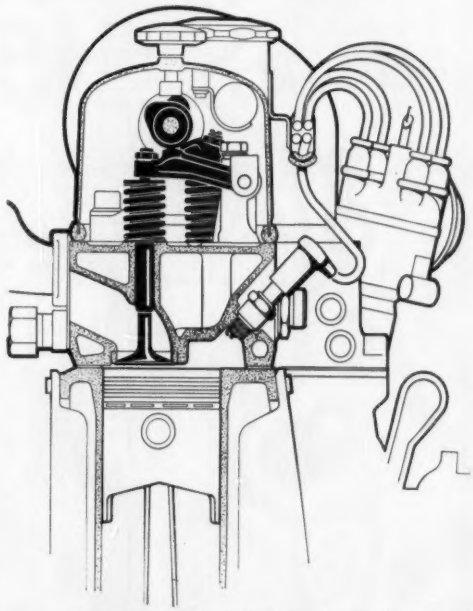
Figure 13 — Ford Taunus 17 M engine showing pushrod operated overhead valve system.

the average United States and European car engine, both develop comparable power per unit of displacement. The average specific output of all 1958 United States production is 0.78 BHP/cubic inch compared to an average of 0.77 BHP/cubic inch for all European engines. Specific output refers to the usable horsepower that can be obtained from a unit of engine displacement. A value of 0.5 BHP/cubic inch indicates that only one-half a horsepower can be obtained for each cubic inch of engine displacement. The higher the number, the better utilization the engine designer has made of the available displacement. A high number, therefore, indicates a more highly tuned and stressed engine, but does not necessarily predict fuel economy. Usually a highly tuned engine will give poorer fuel economy than an untuned version of the same design. Maximum engine speeds are also higher in European cars than those normally encountered in United States production. These may frequently exceed 5000 RPM, whereas the maximum engine speeds of current United States production cars rarely reach this value.

Aside from the similarity of the average specific outputs of both United States and foreign cars, there are many European cars whose specific output exceeds 1.0, whereas only one United States manufacturer exceeds 0.88 BHP/cubic inch. This high value is not limited to racing engines but is obtained by several production engines which are meant to be used by the general public. Among these are the Alfa Romeo Super Sprint, Jaguar Mark VIII and XK 150, Aston-Martin DB-2, Frazer-Nash Sebring and Turismo, Mercedes-Benz 190 SL and 300 SL, MG Twin Cam, Maserati, Porsche 1500 GS and Spyder, and the Saab GT 750. These relatively high values attest to the degree of tune which is in common use in many European engine designs. However, these high specific outputs are usually found only in those cars where high performance is desired. As indicated in Table I, the majority of European cars have more modest specific outputs. In the United States, where there are no restrictions on engine size, satisfactory performance is obtained by using a bigger engine. Therefore, there is no need to use such refined designs.

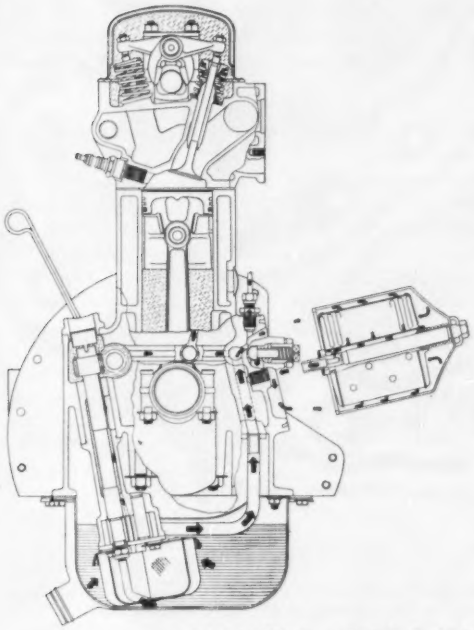
VALVE SYSTEMS

Although physical engine size and power output are the most noticeable differences when discussing European cars, there are many other design features



Courtesy of Studebaker-Packard Corp., South Bend, Indiana

Figure 14 — Mercedes-Benz 190 SL engine showing single overhead camshaft and valves.



Courtesy of The Rover Co. Ltd., England

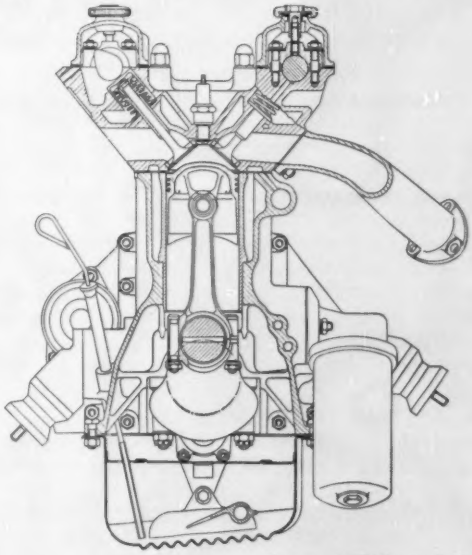
Figure 15 — Singer Gazelle engine showing single overhead camshaft and valves.

which vary considerably from what are normally found in those cars manufactured in the United States. For example, all American cars use either a push rod operated overhead valve arrangement or an "L" or "F" head valve arrangement. In the push rod operated overhead valve system, the camshaft is mounted in the cylinder block and valve motion is transmitted through a system of push rods and rockers. This design is extensively used by almost all of the European cars of which typical examples are found in the Renault Dauphine and Ford Taunus 17 M engines which are shown in Figures 6 and 13. This valve operating system has several advantages, one of which is that it permits the placing of both the intake and exhaust valve in the cylinder head. Such an arrangement allows a smoother gas flow path and a high compression ratio, both of which permit a higher specific output than can be obtained in either the "L" or "F" head designs. In addition, manufacturing costs are relatively low. No complicated cam drive mechanisms are needed since the camshaft is relatively close to the crankshaft.

Aside from engine design refinements such as the overhead valve system, higher specific outputs are also obtainable through the use of higher engine speeds. This is particularly true of European cars where displacements are limited. Due to the limitations of valve system inertia, a push rod operated system generally does not give satisfactory results at high engine speeds. At greater speeds, valve "float" and "bounce" occur. These can best be described as a situation where the engine RPM is so high that the valve springs, which close the valve, are insufficiently strong to overcome the valve system inertia. Under these conditions, the valve motion does not follow the cam profile and the valve stays open longer than it should. In some cases the valve may be struck as the piston comes to the top of its stroke, thus causing both piston and valve damage. Aside from these rather serious results, valve breakage may also occur due to the severe forces imposed on the valve resulting from its uncontrolled motion. Similar destructive forces may also cause camshaft and/or tappet distress. In addition to possible structural damage, valve float causes a loss of power which also limits the maximum obtainable engine speed. Valve float can be controlled to some extent by the use of heavier or dual valve springs which increase the closing spring pressure to which the valve is subjected. However, this remedy tends to overstress the valve system if carried too far.

This problem is not too serious in the majority of European cars since the maximum possible power output is not needed or desired in the family sedan. In the United States, displacements are sufficiently large to permit sufficient power development at engine speeds below the point where valve float becomes a problem.

However, sports and racing cars, since their dis-



Courtesy of Alfa Romeo, Italy

Figure 16 — Alfa Romeo Giulietta engine showing double overhead camshafts and valves.

placements are usually limited by class or formula, must use high engine speeds for maximum power development and, therefore, have turned to other means of overcoming this problem. This is done through the use of either one or two overhead camshafts. These designs place the camshaft near the valve and thereby reduce the number and weight of the valve train parts. This in turn reduces the valve system inertia. Single overhead camshaft designs are somewhat more expensive than the push rod operated valve systems, but they do meet most of the requirements for a valve system that is to be operated at high speeds. Typical examples of single overhead cam designs are shown in Figures 14 and 15 which depict the Mercedes-Benz 190 SL engine and the Singer. Other engines such as the AC, Lloyd, Lotus and Maserati also use this general design. Referring to Figures 14 and 15, it can be seen that this design transmits motion to the valve through very short, relatively light weight rocker arms which have low inertia. Using this design, engine speeds over 6000 RPM are not uncommon.

A further refinement of this design is the use of double overhead camshafts. This is used in several engines such as the Jaguar XK-150 and Alfa Romeo which are shown in Figures 11 and 16. This arrangement further reduces the valve system inertia and permits the highest attainable engine RPM of any conventional valve system design.

Since the valve motion of all of the above systems is not positively controlled and is entirely governed by the ability of the valve springs to make the valve system follow the prescribed cam motion, valve float can occur in any of these arrangements if the engine

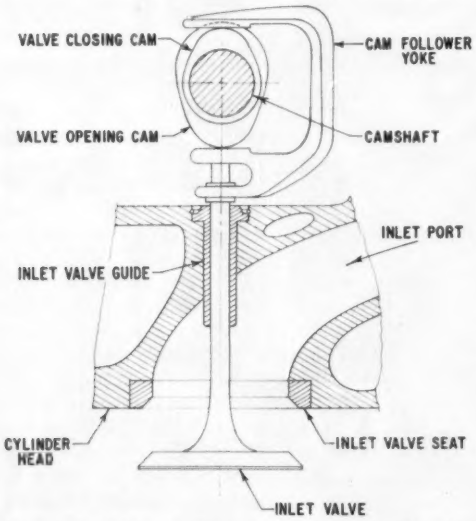
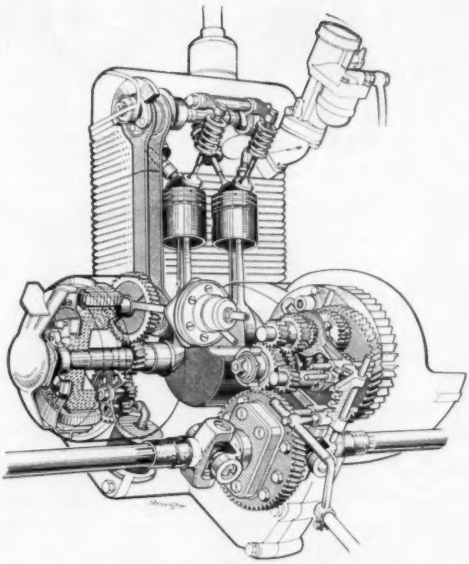


Figure 17 — Schematic diagram of a Desmodromic valve system.



Courtesy of Neckarsulm Werke AG, Germany

Figure 18 — N.S.U. Prinz II engine showing articulated overhead camshaft operating gear.

speed is sufficiently high. In addition, should more rapid opening and closing rates be desired to improve engine "breathing", valve bounce and float can also occur. To overcome these problems and still use very high opening and closing rates, Mercedes-Benz used a "desmodromic" valve system for their W-196 Grand Prix racing car. In this design, illustrated schematically in Figure 17, the opening and closing valve motion is positively controlled by the cam and no valve springs are used. In this system, extremely high opening and closing rates can be employed and long valve "dwell" periods can be used. This permits the valve to open quicker, stay open longer, and close faster than more conventional systems, thus giving improved engine "breathing" which allows a considerable boost in the specific engine output, particularly at high speeds.

Almost all overhead valve operating mechanisms are operated from the crankshaft through either gears or chains. One interesting design which does not use either chains or gears is the N.S.U. Prinz II This design utilizes a pair of connecting rods operating from eccentrics on the crankshaft to transmit a rotation to the camshaft which has similar eccentrics. This eliminates the need for gears or chains and presumably reduces the cost of the overhead camshaft design. This design is shown in Figure 18.

Lubrication of Valve Systems

The lubrication of overhead valve systems is not extremely difficult although a good quality lubricant

is a "must," since high specific loads exist between the tappet and the camshaft. In addition, scoring of the valve rocker shafts or valve stems may also occur should the oil be deficient in load carrying ability. Aside from the loads involved in these systems, the overhead valve chamber is usually the coolest place in the engine and, therefore, tends to accumulate and condense the water formed by combustion of the fuel. This is especially true if the car is used for short trips where it is not thoroughly warmed up. This condensation of water tends to cause rusting of the valve covers and valve springs. The resulting corrosion of the valve cover causes small abrasive flakes of rust to fall into the oil and promote wear. Corrosion of the valve springs tends to cause early valve spring failure, particularly under highly stressed conditions.

To overcome these difficulties, a good grade of detergent oil is required. Most "HD" oils will materially reduce wear of the valve system and also protect against corrosion and possible valve spring failure.

COMBUSTION CHAMBER DESIGN

Aside from the overhead valve systems discussed above, both United States and foreign manufacturers utilize the "L" and "F" head arrangement.

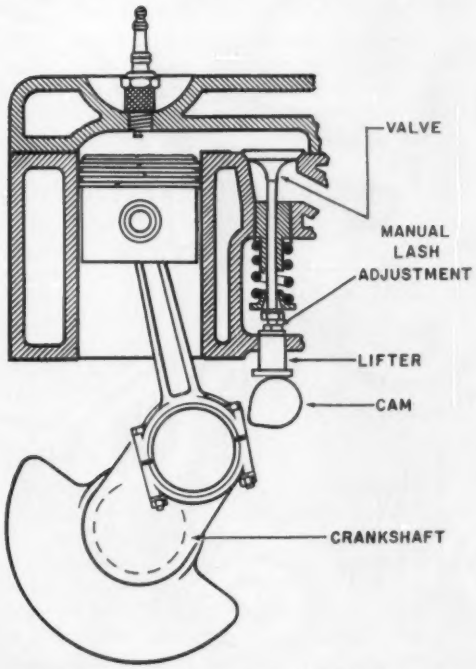


Figure 19 — Schematic diagram of an "L" head combustion chamber showing volume necessary to allow valve clearance and gas transfer.

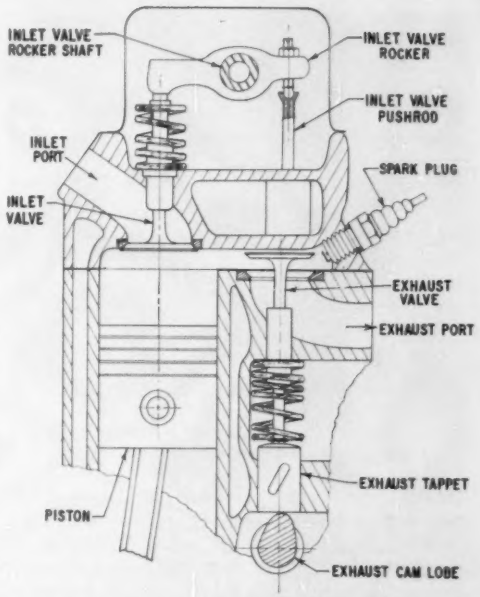
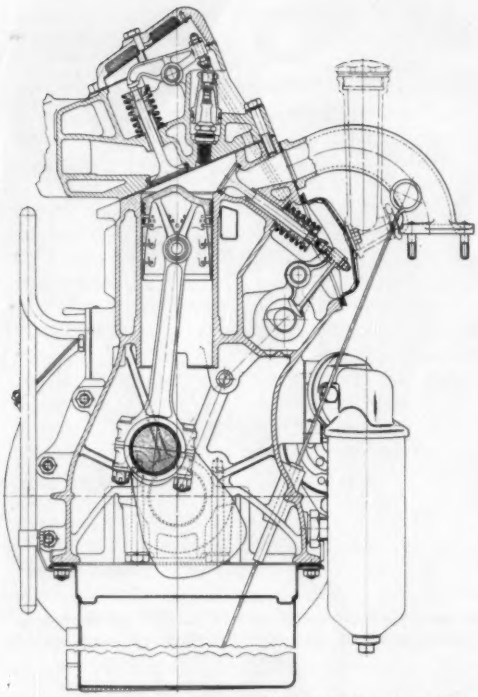


Figure 20 — Schematic diagram of an "F" head showing volume necessary to allow valve clearance and gas transfer to the cylinder.

The "L" type of combustion chamber has been widely used in this country for many years and is still used in one or two United States models. It is also used in a few models of foreign automobiles, such as the small British and German Fords, the Morgan and the Simca. This design is so arranged that both the intake and exhaust valves are in a cylinder block and operate vertically and parallel to the cylinder bore. This is shown schematically in Figure 19. The head, which contains the combustion chamber, is designed so as to permit the transfer of intake and exhaust gases from the valves to the cylinder. This arrangement restricts the compression ratio which can be used since there is a minimum combustion chamber volume which must be maintained in order to allow for valve opening clearance and gas flow. This in turn limits the specific output of the engine. It is interesting to note that this design is now utilized in but a few engines, both here and abroad.

An improvement of the "L" head is the "F" head design. This has been successfully used by both Bentley and Rolls-Royce for many years. It is also used in a modified form by Rover. The design consists of an intake valve, mounted vertically in the cylinder head, and an exhaust valve mounted in the block. Figure 20 schematically illustrates a typical arrangement. While it is a successful design, it again does not allow a small enough combustion chamber



Courtesy of The Rover Co. Ltd., England

Figure 21 — Rover 90 engine showing modified "F" head combustion chamber and reduced combustion chamber volume.

to permit the high compression ratio necessary for high specific outputs. The combustion chamber must again make room for the exhaust valve to open and allow for gas transfer to the exhaust valve. This limits the minimum size of the combustion chamber. It does have an advantage, however, in that the size of the intake valve is not limited and may, therefore, be as large as necessary to permit good mixture induction.

A variation of this design is also used in the Rover engine, shown in Figure 21, wherein some of the difficulties mentioned above have been circumvented by placement of the exhaust valve in a more horizontal position. This improves the exhaust gas flow from the cylinder and reduces the amount of combustion chamber volume which must be allowed for the exhaust valve motion and gas flow. It also permits good intake gas flow since the intake valve size is not limited.

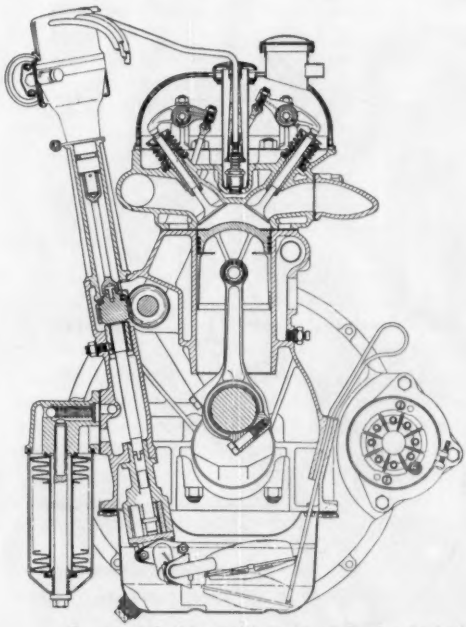
A majority of the push rod-operated overhead valve designs use a modified wedge-shaped combustion chamber wherein the valves are arranged vertically. Typical examples of this type of design are found in the Renault Dauphine, Triumph TR-3, and Ford Taunus 17M, shown in Figures 6, 9, and 13. Some manufacturers while using push rod operated overhead valves, use special designs so as to incline the valves and obtain a hemispherical combustion chamber. Such a design is found in the Armstrong Siddeley Sapphire Engine shown in Figure 22.

In overhead camshaft engines the use of inclined valves can more easily be attained. Typical of these designs is the Lloyd 600 shown in Figure 3. While this is an air cooled engine it does show the general placement of parts which are necessary to attain the hemispherical combustion chamber with a single overhead camshaft.

The use of double overhead cams not only facilitates inclined placement of valves but makes it almost a necessity. For this reason most if not all double overhead camshaft designs utilize the hemispherical combustion chamber. A typical arrangement of this type can be found in the Alfa Romeo shown in Figure 16.

OTHER ENGINE DESIGN FEATURES

Aside from cylinder arrangement and valve systems, most foreign engines are more or less conventional in design except that several such as the AC, Renault, Triumph TR-3, and Alfa Romeo utilize wet sleeve construction. This means that the cylinder is not an integral part of the engine block, but is removable and therefore can be replaced readily should the need arise. This arrangement has some



Courtesy of the "Automobile Engineer," London, England

Figure 22 — Armstrong Siddeley Sapphire engine showing pushrod operated overhead valves and hemispherical combustion chamber.

advantages in that it assures that the cooling rate from the cylinder wall is essentially constant throughout its circumference since the cylinder wall is of uniform thickness. It also permits the use of special alloys for the cylinders which would not be practical for use in the entire cylinder block assembly.

COOLING SYSTEMS

Aside from the air-cooled engines mentioned above, cooling systems are also rather conventional. All engines of recent manufacture utilize a pressure type of cooling system operating between three and fifteen pounds per square inch. In most instances the radiator is placed ahead of the engine. However the DKW, Renault, Saab and Citroen DS-19 among others place the radiator behind the engine. The Fiat 600 places the radiator besides the engine to conserve space.

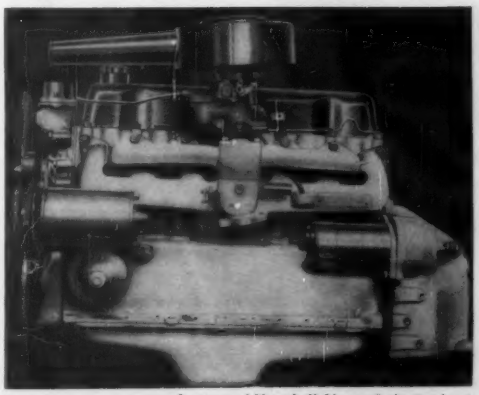
IGNITION SYSTEMS

Ignition systems are also generally conventional with the exception of some of the racing engines which utilize twin ignition to fire two spark plugs per cylinder. Most use battery ignition operating through a conventional distributor and coil arrangement although a few use a magneto to generate the spark. As mentioned previously, under our discussion of the economy car, the four-stroke Citroen 2CV, as well as several of the two-stroke engines, utilize a simplified ignition system wherein no distributor is used and the spark plugs are fired every revolution of the engine. No American design utilizes this feature with the exception of the Harley-Davidson motorcycle.

FUEL SYSTEMS AND REQUIREMENTS

Fuel systems and carburetors are generally conventional with a few exceptions. A few manufacturers utilize a fully pressurized fuel system in which the pump is placed in or near the fuel tank and the complete system from the tank to the carburetor is pressurized. Among those which utilize this system are the Mercedes-Benz 300 SL and the Jaguar Mark VII and XK-150. Needless to say this arrangement considerably reduces the chance of vapor lock and the embarrassment of having a stalled engine in heavy traffic.

Many cars use only one carburetor, even when feeding four or six cylinders. Examples of this are the Vauxhall Cresta six-cylinder engine which is shown on Figure 23 and the Renault Dauphine engine which is shown on Figure 6. In those engines where high performance is desired, it is the custom to utilize two or more carburetors to feed four or six cylinders. These may either be of downdraft or sidedraft design. A typical example of the two carburetor downdraft design is the Mercedes-Benz 220S engine, which is shown in Figure 24. There are



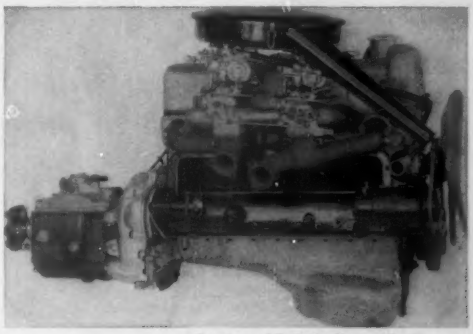
Courtesy of Vauxhall Motors Ltd., England

Figure 23 — Vauxhall Cresta six cylinder engine showing single Zenith downdraft carburetor.

several manufacturers, particularly British, who use a sidedraft S.U. or an Amal carburetor. Both these designs use a sliding piston which completely fills the carburetor air passage. As the throttle is opened, the piston slides up and uncovers some of the throat area and permits the passage of the desired amount of air. The advantage of this design is that at full throttle the piston is completely withdrawn and the air flow to the engine is unrestricted. In a conventional carburetor both the throttle shaft, throttle plate and the auxiliary venturi are in the direct path of the air flow and thus tend to restrict its flow. For the most part, the use of the S.U. carburetor is restricted to those engines which can use a side mounted carburetor.

Typical examples of this type of installation are found in the Jaguar XK-150 engine, which is shown in Figure 11 and the Volvo PV-444L engine which is shown in Figure 25.

While carburetors are almost universally used in Europe, there are two German engines which utilize



Courtesy of Daimler Benz AG, Germany

Figure 24 — Mercedes-Benz 220S six cylinder engine showing twin Solex downdraft carburetors.

fuel injection. These are the Goliath two-cycle engine and the Mercedes-Benz 300 SL engine. Both of these utilize direct cylinder injection. Mercedes-Benz also uses fuel injection in their 300 D engine. However, in this design the fuel is injected into the intake port prior to its entry into the cylinder.

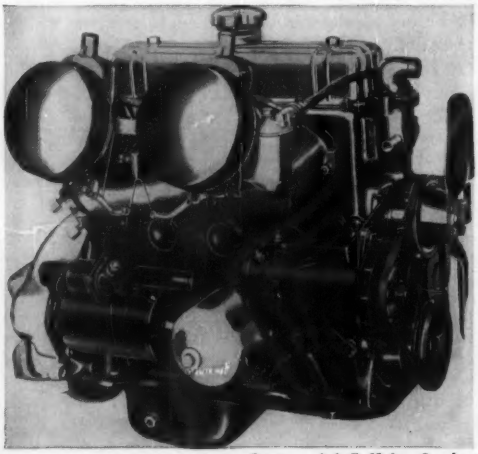
The fuel requirement of the average European car, especially as imported into the United States, is not critical. Their basic designs utilize compression ratios and spark advances which are satisfactory for European fuels whose octane values are generally below those obtained in the United States. Even when compression ratios and spark advances are changed so as to make better use of the higher octane fuels available in the United States, their octane requirements are generally well below the octane of domestic premium fuels.

Fuels containing Tetra Ethyl Lead (TEL) are widely used in Europe, consequently European cars have been designed to utilize its benefits. Non-leaded fuels are not necessary and will be harmful if they have inadequate octane or gum stability.

LUBRICATION SYSTEMS

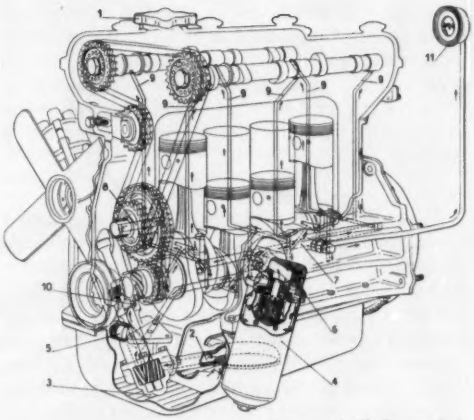
For the most part, European engine oil systems are similar to those used in the United States. They are full pressure systems incorporating a full flow oil filter. Splash lubrication is almost non-existent except in some of the older engine designs. Two-stroke engines use oil added to the gasoline as discussed earlier. An example of a modern fully pressurized oil system which is equipped with a full flow filter is found in the Alfa Romeo Giulietta shown in Figure 26.

A few manufacturers continue to specify certain brand names which are to be used in their cars, and these brand names are shown in the owner's manual as well as on a nameplate attached to the fire wall or to the engine filler cap. The practice of recommending products by brand name tends to give the impression that only those oils will be satisfactory in the engine. However, most manufacturers will approve, upon inquiry, any good quality oil. This would include a majority of the oils manufactured in America.



Courtesy of A. B. Volvo, Sweden

Figure 25 — Volvo PV-444L four cylinder engine showing twin S.U. side draft carburetors.



Courtesy of Alfa Romeo, Italy

Figure 26 — Alfa Romeo Giulietta engine showing fully filtered pressurized oil system.

1. Oil (lubricant) feeding union.
2. Picking up from the sump through oil filter.
3. Lubricant Pump.
4. Oil Filter.
5. Safety Valve (Pressure Relief Valve).
6. By Pass Valve for excluding the filter in case of clogging.
7. Main oil gallery.
8. Duct for the lubrication of intermediate gear.
9. Ducts for lubricating of the camshafts.
10. Duct for the lubrication of distributor control gears.
11. Oil gauge.

A more complete discussion of the engine lubrication requirements will be included in a subsequent issue of "Lubrication". This will cover such points as oil quality, viscosity recommendations and drain periods. In addition, a discussion of the lubrication requirements of other chassis units such as the transmission and differential will also be included.

SUMMARY

European cars are becoming an increasing economic factor in the domestic automotive picture. They are available in a wide variety of sizes and designs many of which contain unusual features. Engine sizes are small compared to United States standards although their specific power outputs are comparable. Fuel economies are generally higher due to their smaller engine size and lighter chassis weights. European cars can successfully use the petroleum products that are available in the United States.

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